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# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

INDEXED

PROJECT NO. 1 - COLD WEATHER OPERATIONS

Second Partial Report  
On

Sub-Project No. 1-19, Study of the Physiological Effects of Cold

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Project No. 1-19

16 June 1945





ARMORED MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

Project No. 1-19  
SPMEA 727-1

16 June 1945

1. PROJECT NO. 1 - Cold Weather Operations. Second Partial Report on Sub-Project No. 1-19, Study of the Physiological Effects of Cold.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose - To study the differences in responses of men to cold.

2. DISCUSSION:

a. There are significant variations in the subjective responses of men to cold. On the basis of this variability men have been broadly classified as being relatively resistant, intermediate, or susceptible. A previous report\* presented a detailed discussion of these types, the procedure for selection, and the lack of correlation between sensory and thermal experiences. The data presented therein were obtained during three (3) successive morning exposures for each man. Since the completion of that preliminary survey an additional fifty (50) men have been tested and of these, a representative group of ten (10) subjects have been exposed to the cold for a period of thirty-one (31) days. The data obtained form the basis of the present report. This study was part of the broader program of evaluation of clothing and since the findings will be of interest to testing agencies, the analysis of data is being reported.

b. During our earlier studies of cold weather clothing, we attempted to expedite our testing by making two (2) tests in a single day. This was discontinued since the men exhibited markedly different behavior patterns in the morning and afternoon exposures. Specific investigation of this phenomenon was not possible at that time. During the present tests, observations were deliberately made during successive morning and afternoon exposures. Also, on a few days, the men did not enter the cold room in the morning, the first exposure of the day being in the afternoon.

3. CONCLUSIONS:

a. The variations in sensory experiences of men exposed to the cold are significant. While men may be classified as resistant, susceptible or intermediate, only the resistant may be considered to be relatively stable. Susceptible and intermediate men exhibited marked daily variations.

\* Sub-Projects 1-1, Partial Report on Test of the Adequacy and Range of Winter Clothing and 1-18, Study of the Methods for Selection of Men for Cold Weather Operations, dated 1 April 1944.





b. The sensory organs which respond to cold stimuli appear to make an adaptation which persists for several hours following return to ordinary environmental temperatures. An afternoon exposure, following a three (3) hour morning exposure, does not result in such acute sensory experiences as are present during first exposure (morning or afternoon).

c. There is need for further study to determine the basic cause of variations in man's sensory response to cold and the factors leading to the marked daily variation in some men.

d. The considerable variation in the sensory responses of men belonging to the intermediate and susceptible groups makes the use of individuals of these groups of questionable value in clothing tests.

4. RECOMMENDATIONS:

a. No specific recommendations are made.

b. This report is being distributed to agencies concerned with the testing of clothing and equipment.

Prepared by:

Steven M. Horvath, Major, SnC  
Howard Golden, Tec 3  
John Wagar, Tec 3

APPROVED

*Willard Machle*  
WILLARD MACHLE

Colonel, Medical Corps  
Commanding

2 Incls.

#1 - Appendix

#2 - Charts 1 thru 9





## APPENDIX

### 1. Procedure:

a. Two (2) series of tests were conducted. In the first, fifty (50) men were processed to determine their relative resistance to cold and to classify them into categories representing three different degrees of tolerance to cold. From this group ten (10) representative men were selected for the second series of tests. These men were employed primarily as subjects for a series of clothing studies but were retested at intervals for their susceptibility to cold. Subjective responses were obtained during three (3) hour periods of exposure to environmental temperatures of  $-18^{\circ}$ ,  $-23^{\circ}$ ,  $-27^{\circ}$ , and  $-36^{\circ}\text{C}$ . Measurements of skin and rectal temperatures were made on a number of subjects. Since the intention of this investigation was to observe differences in relative resistance to cold, the subjects wore the same type of clothing in all tests.

b. The subjective sensations of cold which have been found to be most precisely reportable are the onset of pain in the fingers, onset of pain in the toes and the onset of shivering. The criteria established in our previous report for the segregation of men into general classes of cold resistance are defined as follows, based upon a single exposure to the cold:

Susceptible: When two (2) of the three (3) manifestations of discomfort appear within two (2) hours without exceptional resistance in the third modality.

Resistant: When two (2) of the three (3) manifestations of discomfort do not appear within three (3) hours and the third not before one and a half hours.

Intermediate: Subjects not included in above two (2) groups.

### 2. Selection Tests:

a. A group of fifty (50) men were tested at an ambient temperature of  $-27^{\circ}\text{C}$  with zero wind velocity. On each successive day a group of ten (10) men came to the laboratory. After being fitted with a Standard Arctic clothing assembly, they were taken into the cold room to sit quietly for a period of three (3) hours. The same men returned for another test in the afternoon, approximately two (2) hours after the cessation of the morning exposure. Lunch was eaten one to one and one half hours prior to re-entering the cold room. The only data obtained were subjective responses to the cold and rectal temperatures before and after each exposure.

b. The clothing worn by this group consisted of the following:

Underwear, Wool, 50/50	Socks, Wool, Cushion Sole, 1 pair
Trousers, Field, Pile	Socks, Wool, Ski, 2 pairs
Trousers, Field, Cotton, O.D.	Shoe, Arctic, Felt
Jacket, Field, Pile	Mitten, Insert, Trigger Finger, M-1943
Parka, Field, Pile	Mitten, Shell, Trigger Finger, M-1943
Parka, Field, Cotton, O.D.	





b. The times for the onset of the subjective sensations in this group of fifty (50) men during their morning exposure are shown in Fig. 1. On the basis of the previously proposed classification, nine (9) men can be considered resistant and twelve (12) men susceptible. These men are identified in the chart (Fig. 1). The results obtained with this group agree fairly well with those obtained on the group of fifty-six (56) men studied previously. The distributions into the three categories is shown for the two (2) groups in Fig. 2. The comparative percentages for the present and the earlier group respectively are: Resistant, 18 and 21 per cent; Susceptible, 24 and 43 per cent; Intermediate, 58 and 45 per cent. The classification based on single exposures is slightly more stringent than when based on three (3) exposures. This may account for the greater percentage of intermediates in the present group.

c. The results of the afternoon exposure on these men were markedly different from the morning observations. Only three (3) of the (50) men reported the occurrence of any subjective sensations of discomfort. These three (3) had been classified as intermediate reactors on the basis of their morning exposure. Subject Ti. reported onset of pain in his toes in eighty-five (85) minutes, Di. had pain in the toes in one hundred fifteen (115) minutes and shivering in one hundred ten (110) minutes, and Wz. started to shiver at one hundred ten (110) minutes. The results of the afternoon test suggested that forty-seven (47) men were resistant and three (3) were intermediate. Further investigation of this phenomenon was felt necessary.

### 3. Retest:

a. From the above group of fifty (50) men, ten representative individuals were selected to act as subjects for some clothing studies. Before and during the progress of these tests a number of observations were made on these subjects dressed in a standard Arctic clothing assembly.

#### Control Clothing Worn by Subject in These Tests.

Drawers, Wool, 50/50  
Undershirt, Wool, 50/50  
Shirt, Flannel, O.D.  
Trousers, Field, Wool, O.D.  
Trousers, Field, Pile  
Trousers, Field, Cotton, O.D., Sateen, 9 oz.  
Parka, Field, Cotton, O.D., Sateen, 9 oz.  
Parka, Pile  
Shoe, Arctic Felt  
Socks, Wool, Ski ( 2 pairs)  
Socks, Wool, Cushion ( 1 pair)  
Mittens, Insert, Trigger Finger M-1943  
Mittens, Shell, Trigger Finger M-1943  
Mufflers, Wool  
Wristlets, Knit

b. Two types of tests were made: (1) repeated observations of the men during the progress of the clothing tests to determine the stability of their responses to the cold over a period of consecutive acute exposures and (2) observations on successive morning and afternoon exposures either preceding or following an afternoon exposure made without a previous morning exposure. Records were ob-





tained primarily on the subjective sensations experienced by the subjects. However, objective measurements, such as skin and rectal temperatures and metabolic rates, were obtained on six (6) of the subjects.

c. The men reported at the laboratory at 0645 hours, ate a standard breakfast, lounged around until it was time to dress to enter the cold room at 0830 hours. If no exposure was planned for the morning, they returned to their barracks or helped around the laboratory until lunch at 1145 hours. They then returned to the laboratory for their afternoon exposure beginning at 1400 hours. All exposure periods were of three (3) hours duration at the ambient temperatures noted, usually  $-23^{\circ}\text{C}$ . Four (4) of the subjects (Ba., Gr., Va., and He.) were exposed to wind velocities of either zero (0), five (5) or nine and six tenths (9.6) miles per hour in order to determine the influence of both air movement and cold on their reactions. The remaining six (6) subjects were not exposed to wind during these tests.

#### 4. Tests at Zero Air Movement:

a. Data on the subjective reactions of six subjects exposed to still air at  $-23^{\circ}\text{C}$  are presented in Figs. 3 and 4. The greatest number of observations made on any single subject during the thirty-one (31) days of exposure was nineteen (19). On the basis of information gathered and for convenience during the following discussion, the subjects were placed into one of two (2) broad groups--resistant (3 men) and variable reactors (3 men).

b. Men who fall into the resistant category in initial tests have a decided tendency to remain in that class. In only one (1) of the three (3) resistant subjects (Fo.) was there observed any significant deviation from the resistant. There were two (2) days in fifteen (15) in which it appeared from this individual's subjective reactions that he might be intermediate instead of resistant. The two (2) remaining subjects (Ch. and Go.) could be classified as resistant in all the observations made.

c. The other three (3) members of this group of six (6) were called variable reactors since their day to day reactions could not be predicted. Ri., varied from resistant to intermediate. During approximately one half of his first fifteen (15) days of exposure he was resistant and during the other half, intermediate, no pattern was observed. Di. and Ti. varied from susceptible to resistant. Ti. was resistant on only a single day, at other times varying from susceptible to intermediate. On the other hand, subject Di. ran the gamut from susceptible to resistant. Again no pattern was observed.

d. These findings are of considerable importance in the interpretation of results in clothing tests which utilize subjective sensations of comfort of the subjects as criteria of adequacy. No certain comparisons of different clothing designs can be made using subjects who are not resistant because their responses are not predictable. Resistant subjects, on the other hand, may not be satisfactory since the differences they may exhibit if stress is not great will be small. It is always possible, however, to cause some resistant men to break down by subjecting them to a greater stress by decreasing the temperatures or by increasing air movement. Only if sufficient subjects are available and a large number of tests are made, is it possible that a statistical analysis can provide an adequate answer from data obtained on the variable reactor groups.





## 5. Tests with Air Movement:

a. The data obtained on the subjective responses to cold reported by the four (4) men who were subjected to three degrees of air movements are presented in Fig. 5. Their pattern of response became more variable and unpredictable. In general, the higher the rate of air movement to which men are exposed, the more rapidly do they experience subjective sensations of discomfort. A single subject, He., was uninfluenced by the increased air movements at  $-23^{\circ}\text{C}$ . The other three subjects were designated as susceptibles in their first test at zero wind. With an air movement of five mph they proved to be resistant, intermediate or susceptible on different days of exposure. The pattern was not regular in that the number of previous exposures had no influence on reactions to cold and wind during the exposure considered. This variability in response is important in the interpretation of the protective value of clothing especially since most previous tests have been performed under conditions of still air or very low wind velocities.

## 6. Successive Exposures:

a. Subjective Sensations. There was considerable discrepancy in the subjective sensations of cold experienced by men who were exposed to low temperatures in the morning and again in the afternoon of the same day. The explanation of the cause-effect relationship was not determined, but some of the details of the differences were clarified. Men were exposed for a three (3) hour period to low ambient temperatures both morning and afternoon. This test day was either preceded or followed by a day in which the men were subjected to either an afternoon or a morning exposure only.

b. The general impression of both the observers and the subjects was that the men were much more comfortable during their second exposure of the day than they were during their first. Data obtained in afternoon exposures without the preliminary morning exposures were very similar to those secured in the usual morning tests. First exposures, regardless of the time of the day when they occurred, appear to be associated with more distressing symptoms of discomfort. Succeeding exposures were in general less severe on the basis of subjective sensations.

c. Differences between the morning and afternoon exposure periods could not be determined on the four (4) men who were classified as resistant since they failed to experience discomfort during their first exposures (Fig. 6).

d. The remaining six men, (variable reactors) exhibited a definite tendency toward greater comfort during their second exposures (Figs. 7 and 8). The real value of the differences for three men shown in Fig. 7 may be open to some question since the group had exhibited considerable variability in their first exposures of the day but the observations were fairly consistent with respect to increased stability and delayed onset of symptoms during the second exposure.

e. The improved performance during the second exposure was most striking in three members of the group exposed to air movement and, hence, greater stress (Fig. 8). In initial tests with still air, none of these men exhibited symptoms of discomfort. However, when wind velocities of 5.0 and 9.6 mph were used considerable disturbances in subjective comfort appeared, as shown in Fig. 8. In all cases the subjects could be classified as resistant during the second exposure of the day whereas they were either susceptible or intermediate during their first exposure.





Results of a single exposure during the afternoon were similar to those observed in the first or a single exposure of the day in the morning.

f. It appears that the subjective sensations of cold experienced by men are influenced to some extent by the condition of the sensory end organs or some other element in the neural chain. The possibility that the end organs responsible for detection of the sensation of coldness have become adapted during the initial period of exposure and do not respond as rapidly and as intensely to the same degree of stimulus during a subsequent re-exposure cannot be ignored. This adaptation or raising of the threshold for cold stimulation appeared to persist for only a period of hours but this was sufficient to lower the intensity of response during the second exposure of the day. Adaptation did not persist overnight. Further investigation into this phenomena must be carried out with subjects who live continuously in a cold environment.

g. The subjective sensations of cold experienced by the subjects on their first and thirty-first day of exposure to  $-23^{\circ}\text{C}$  and zero wind velocity are compared in Fig. 9. Each subject had been exposed to low temperatures for at least one hundred and fifty (150) hours in the interval between these two tests, which were run under as similar conditions as possible. The four subjects who were resistant on their first exposure exhibited the same type of response on their thirty-first. Of the six remaining subjects, five (5) who were classified as susceptible on their first day, were found to be resistant on the last day. All were definitely more comfortable.

h. These apparent changes in subjective susceptibility to cold may have been simply a part of the normal variation observed in this group of subjects. But it may be an expression of the response of the organism to variation in intensity of stress--on the first exposure the conditions appeared psychologically to be intense but repeated exposures to similar or more severe stresses resulted in a diminution of the sensory response or awareness of the intensity of stimulæ and consequent impressions of relative comfort.

i. This is also illustrated by the response of three susceptible subjects to an environment of  $-23^{\circ}\text{C}$  and zero air movement before and after a period of exposure to low temperature and two degrees of air movement (Fig. 5). In tests at zero wind subsequent to these exposures to high air movement they were quite comfortable and could be classed without question as belonging to the resistant group. This suggests that the interim exposure to cold and wind had altered their responses to sensory stimuli and certainly indicates the necessity for careful study of previous exposures in evaluating the reactions of subjects. The importance of previous or succeeding exposure to severe environmental stress in the subjective evaluation of sensory experiences appears to have been underestimated.

## 7. Objective Measurements:

a. The improvement noted in the subjective responses of the men during their second exposure of the day was also observed, although to a less marked degree, in the objective measurements made. Metabolic determinations were made on only two subjects. Their heat production rates were slightly lower in the second exposure. Subject He., who was consistently resistant, had heat outputs of 55, 57 and 65 Cals/ $\text{M}^2$ /Hr. for the first, second, and third hours, respectively, of his morning exposure. Corresponding values were seven (7) to eight (8) per cent lower during the second exposure. The other subject, Gr., exhibited a similar response. The differ-





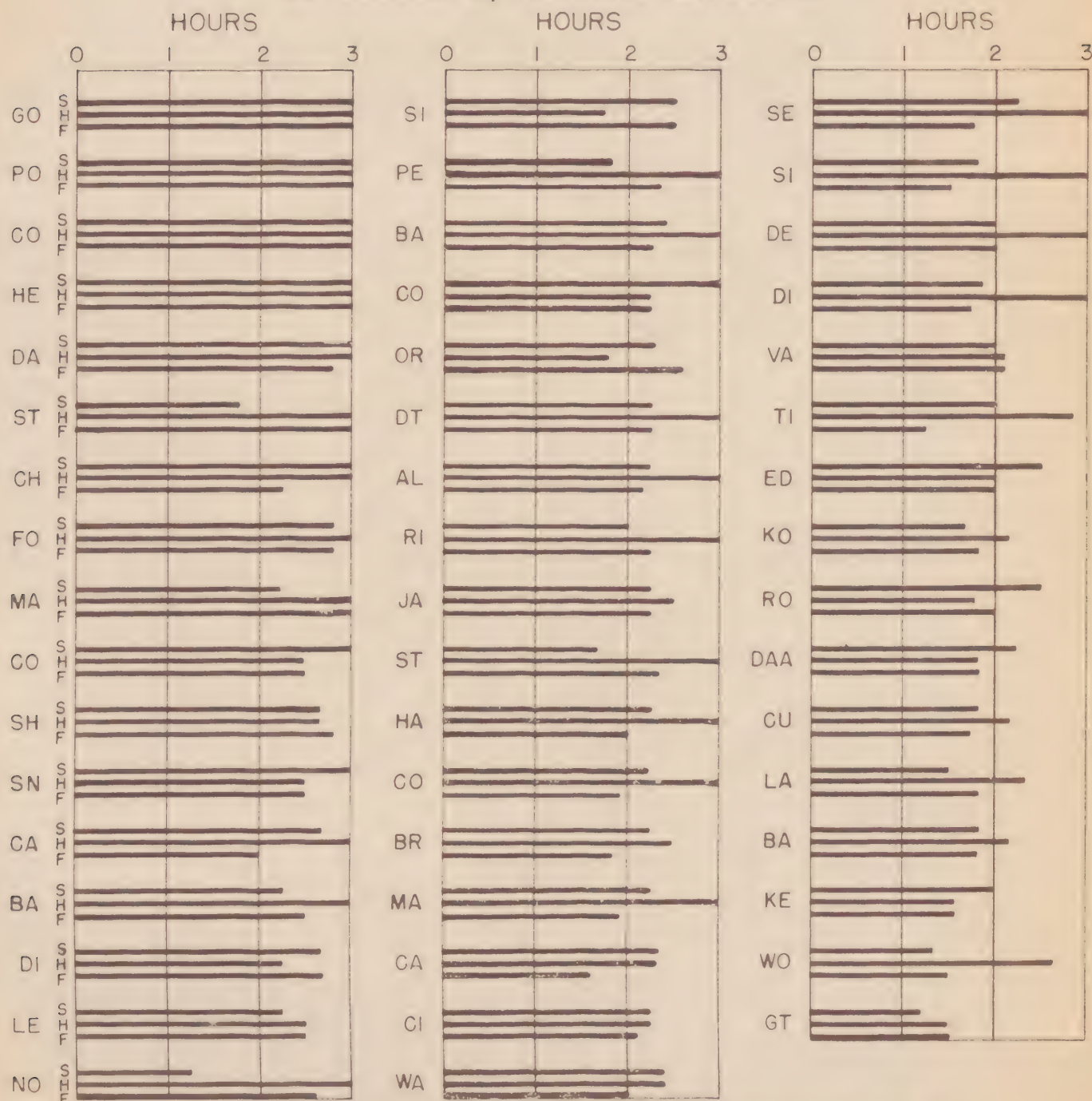
ences are of somewhat doubtful significance since they may merely reflect the diminished intensity of shivering in subject Gr., or a decreased muscular tension in subject He. during the second exposure.

b. Only slight differences appeared in the skin temperature during the different exposures. They indicate a small trend toward a higher skin temperature at the end of the second (afternoon) exposure of the day which was not particularly related to the previous exposure, since higher terminal skin temperatures were recorded in all afternoon tests, whether preceded by a morning test or not. The occurrence of the higher extremity temperatures at the beginning of the second exposure of the day undoubtedly reflects the reactive hyperemia resulting from the previous morning exposure. The mean values for K, the cooling constant, were identical for the first exposures of the day either morning or afternoon, 0.770, but somewhat lower, 0.594, for the second exposure of the day. These differences are again only indicative of trends. The average rectal temperature changes are of some significance in that at the end of the second exposure they were higher than in the first exposures, viz.; A.M. 99.2 to 98.2; P.M. (same day) 99.9 to 98.6; P.M. (next day no A.M. exposure) 100.0 to 98.3. The relationship of these temperature changes to the sensations of discomfort experienced by the men is not clear.





FIG. 1  
TIME OF ONSET OF SUBJECTIVE SENSATIONS OF COLD  
50 SUBJECTS, MORNING EXPOSURE



DURATION OF EXPOSURE TO ONSET OF STATED SENSATIONS, HOURS

— KEY —

F = ONSET OF PAIN IN FEET  
H = ONSET OF PAIN IN HAND  
S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED  
SENSATIONS DURING EXPOSURE

FIG. 1





FIG. 2

PERCENTAGE DISTRIBUTION OF SUBJECTS IN  
TWO EXPERIMENTAL GROUPS CLASSED AS RESISTANT, SUSCEPTIBLE  
OR INTERMEDIATE REACTORS TO COLD

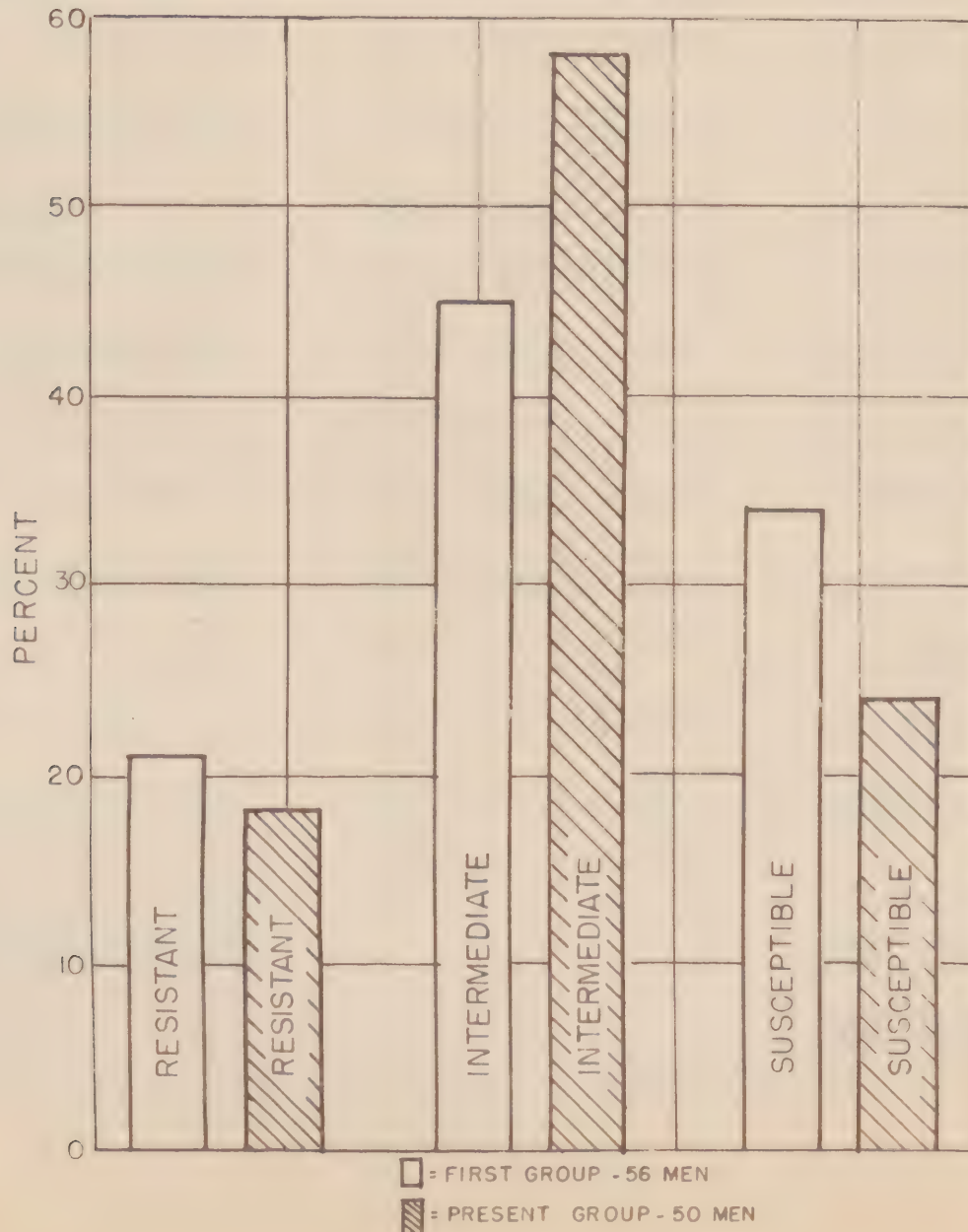






FIG. 3

SUBJECTIVE REACTION OF MEN EXPOSED TO  
-23.3°C (ZERO WIND VELOCITY)

RESISTANT TYPE



DURATION OF EXPOSURE TO ONSET OF STATED SENSATIONS, HOURS

— KEY —

F = ONSET OF PAIN IN FEET  
H = ONSET OF PAIN IN HAND  
S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED SENSATIONS DURING EXPOSURE.

FIG. 3

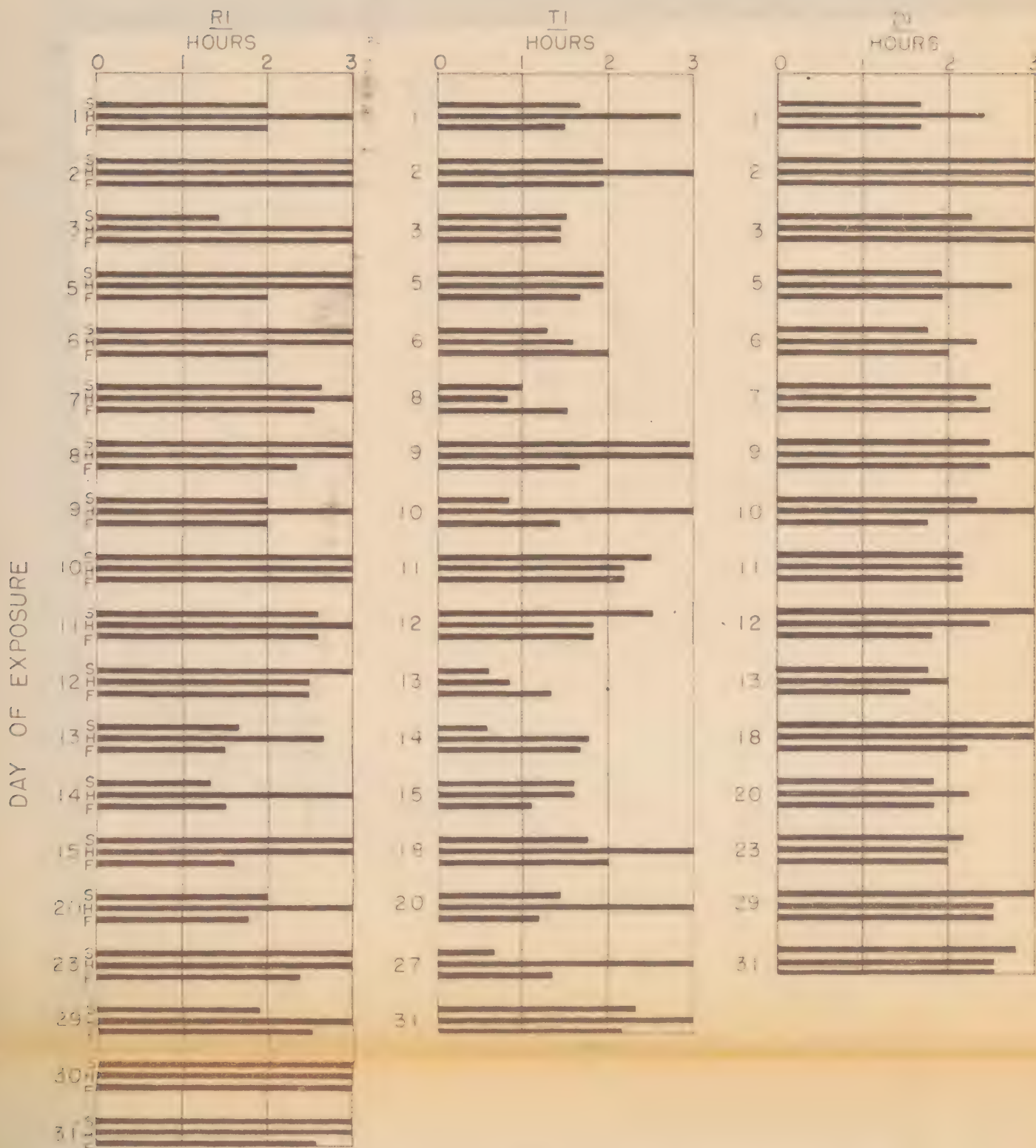




FIG. 4

SUBJECTIVE REACTION OF MEN EXPOSED TO  
-23.3°C (ZERO WIND VELOCITY)

VARIABLE REACTOR TYPE



DURATION OF EXPOSURE TO ONSET OF STATED SENSATIONS, HOURS

— KEY —

F = ONSET OF PAIN IN FEET  
H = ONSET OF PAIN IN HAND  
S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED  
SENSATIONS DURING EXPOSURE

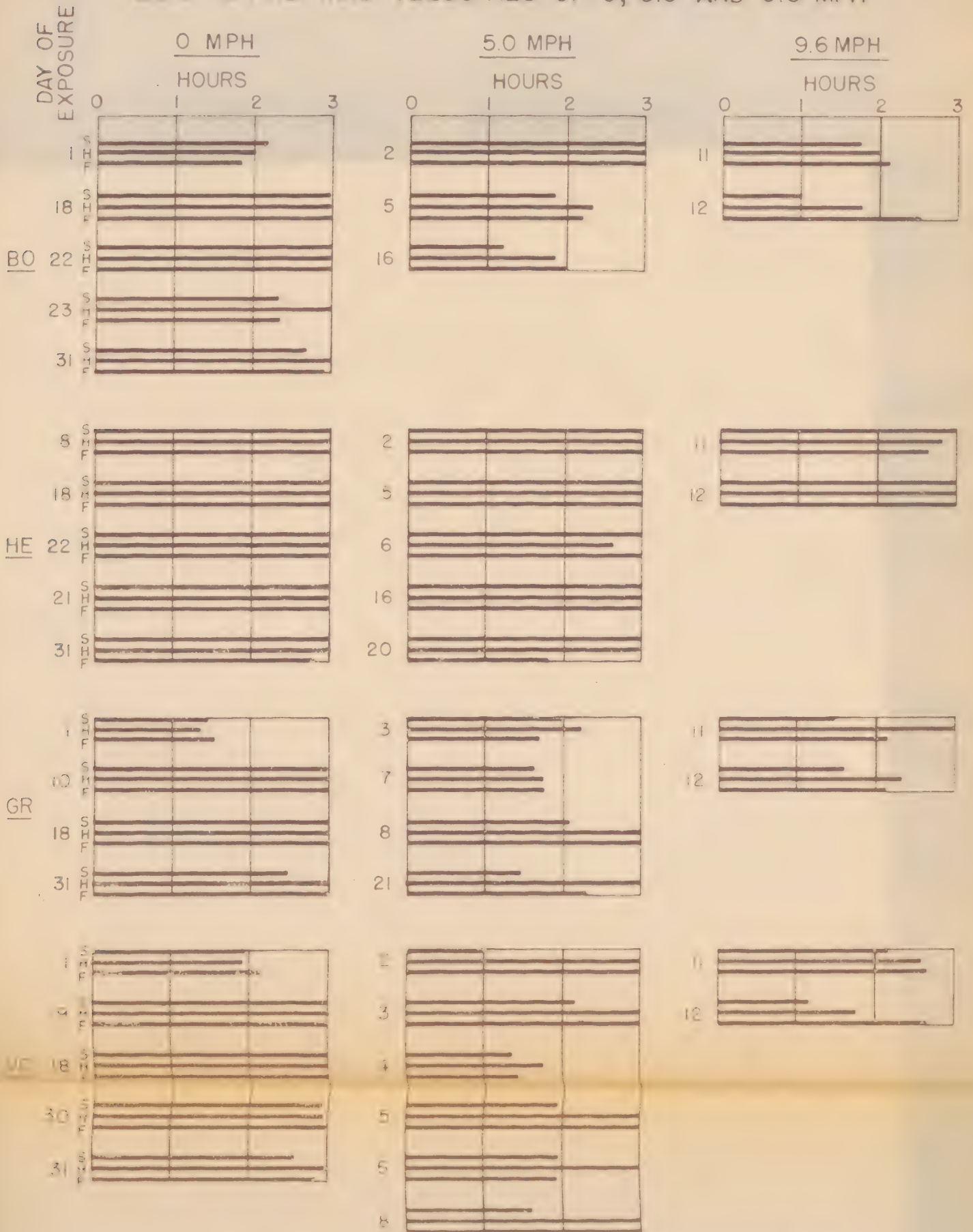
FIG. 4





FIG. 5

TIME OF ONSET OF SUBJECTIVE SENSATIONS OF MEN EXPOSED TO  
-23.3 °C AND WIND VELOCITIES OF 0, 5.0 AND 9.6 MPH



DURATION OF EXPOSURE TO ONSET OF STATED SENSATIONS, HOURS

— KEY —

F = ONSET OF PAIN IN FEET  
H = ONSET OF PAIN IN HAND  
S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED  
SENSATIONS DURING EXPOSURE





FIG. 6

TIME OF ONSET OF SUBJECTIVE SENSATIONS OF COLD IN RESISTANT SUBJECTS DURING THREE HOUR EXPOSURES TO TEMPERATURES OF  $-23.3$  AND  $-27.0^{\circ}\text{C}$

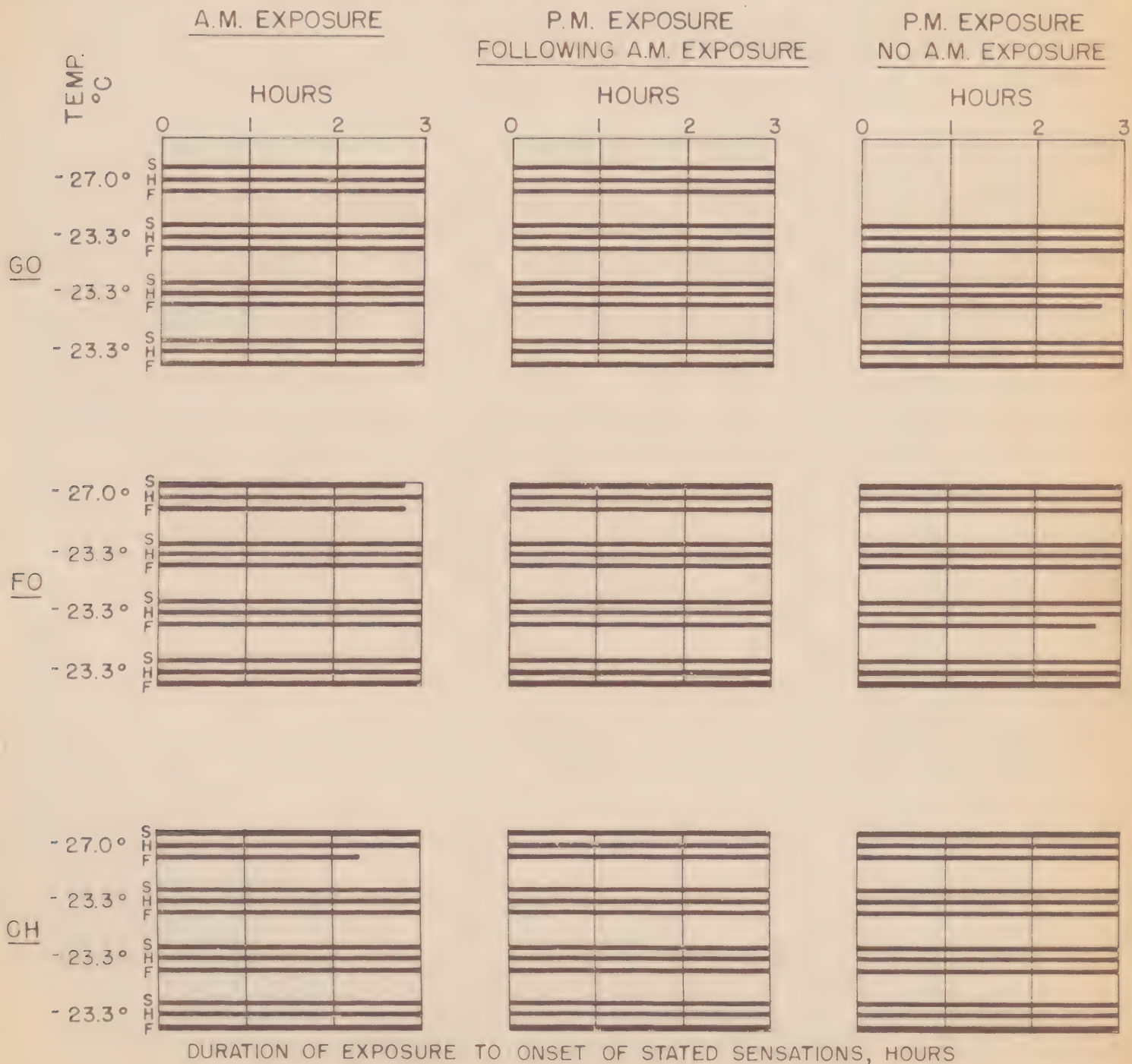
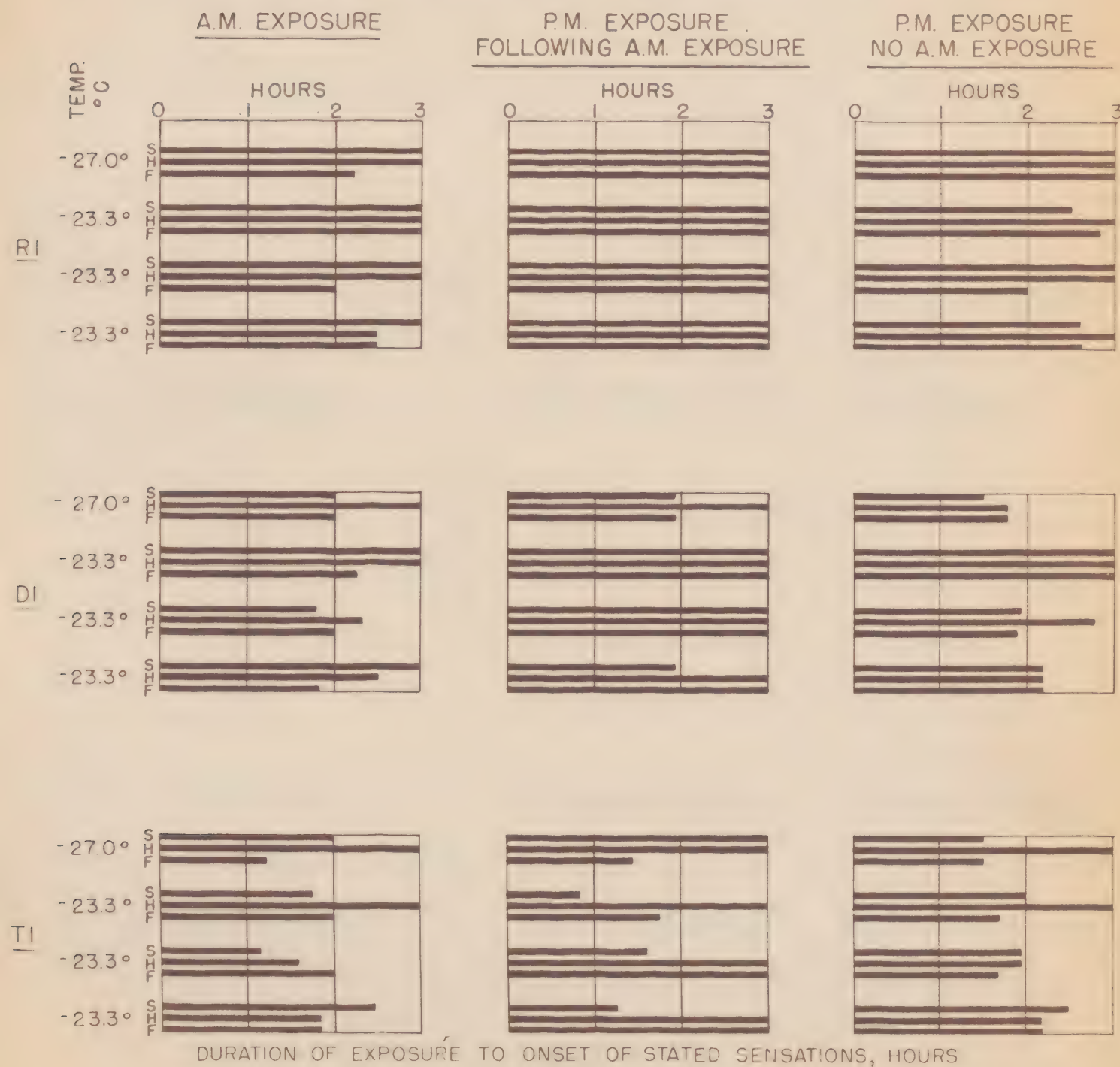


FIG. 6



FIG. 7

TIME OF ONSET OF SUBJECTIVE SENSATIONS OF COLD  
IN VARIABLE REACTORS DURING THREE HOUR EXPOSURES TO  
TEMPERATURES OF  $-23.3$  AND  $-27.0^{\circ}\text{C}$ .



—KEY—

F = ONSET OF PAIN IN FEET  
H = ONSET OF PAIN IN HAND  
S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED  
SENSATIONS DURING EXPOSURE

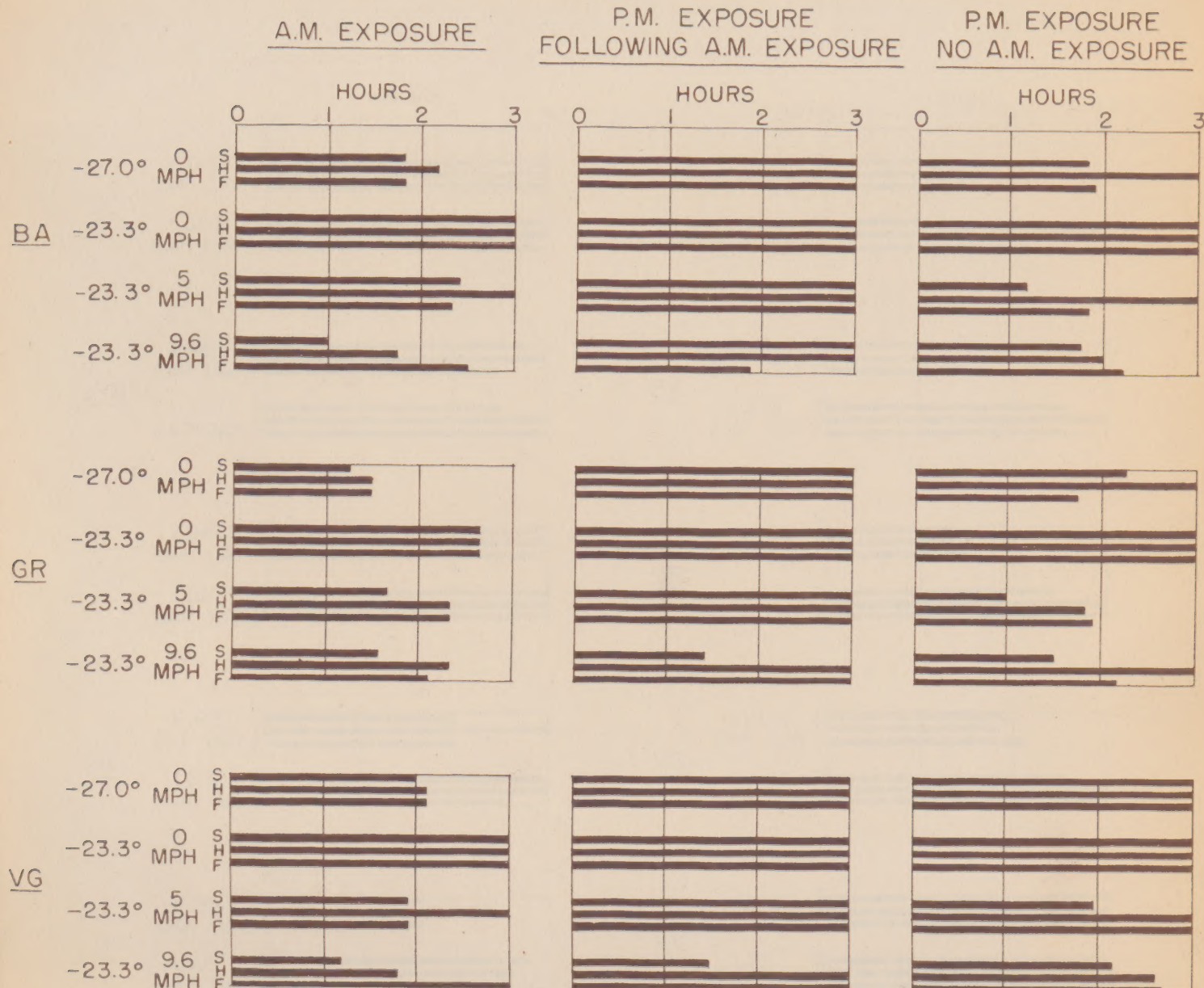
FIG. 7





FIG. 8

TIME OF ONSET OF SUBJECTIVE SENSATIONS OF COLD  
IN VARIABLE REACTORS DURING CONSECUTIVE THREE HOUR  
EXPOSURES TO COLD AND WIND VELOCITIES OF 0, 5, AND 9.6 MPH



DURATION OF EXPOSURE TO ONSET OF STATED SENSATIONS, HOURS

—KEY—

F = ONSET OF PAIN IN FEET  
H = ONSET OF PAIN IN HAND  
S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED  
SENSATIONS DURING EXPOSURE

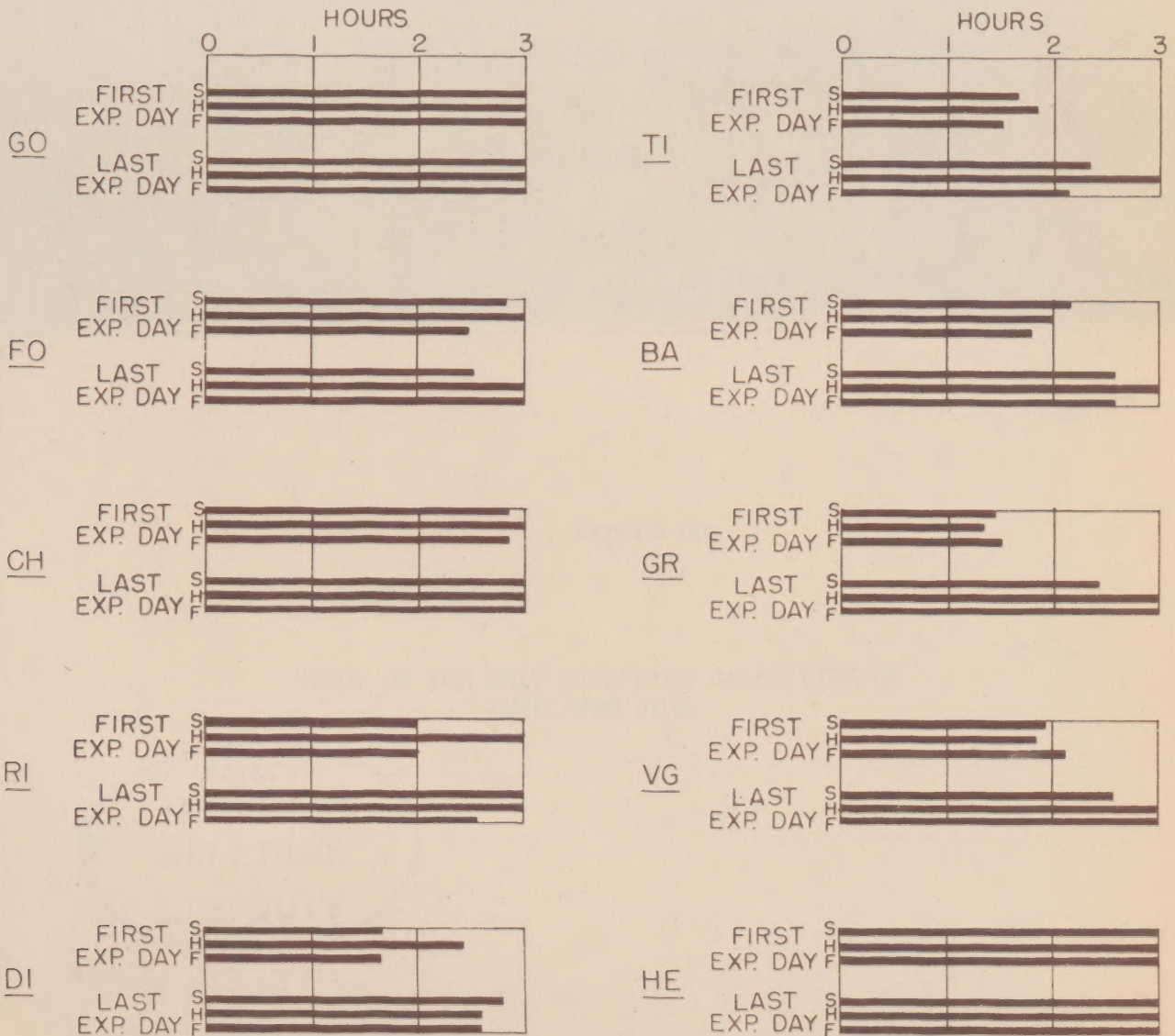
FIG. 8





FIG. 9

TIME OF ONSET OF SUBJECTIVE SENSATIONS OF COLD IN  
TEN SUBJECTS ON THEIR FIRST AND THIRTY-FIRST THREE  
HOUR MORNING EXPOSURE TO  $-23^{\circ}\text{C}$  AND ZERO WIND VELOCITY



DURATION OF EXPOSURE TO ONSET OF STATED SENSATIONS, HOURS

—KEY—

F = ONSET OF PAIN IN FEET

H = ONSET OF PAIN IN HAND

S = ONSET OF SHIVERING

EXTENSION OF LINE TO 3 HOURS INDICATES NO STATED  
SENSATIONS DURING EXPOSURE

FIG. 9

